

Carvin Peters, both



# Liquid Assets

Educational facilities and the fountains of a new plaza are making good use of water from a system that is remediating contaminated groundwater in Wichita, Kansas.

By Paul Anderson, P.E., Roger Olsen, Ph.D., and J. Richard Kaufman, P.E., DEE

The city of Wichita, Kansas, faced a potential crisis when groundwater contaminated with volatile organic compounds was discovered in the downtown area in the late 1980s. The primary chemicals of concern included tetrachloroethene (also known as perchloroethylene, or PCE), trichloroethene (TCE), *cis*-1,2-dichloroethene (*cis*-1,2-DCE), and vinyl chloride (VC). The contaminated groundwater extended beneath approximately 8,000 parcels of land, including more than 550 businesses and hundreds of residential properties, presenting a threat to human health, the environment, and the local economy.

The Kansas Department of Health and Environment (DHE) discovered the contamination through groundwater sampling performed in compliance with the Resource Conservation and Recovery Act (RCRA) at an industrial facility. The resulting environmental investigation and remediation project was

named after the two streets (Gilbert and Mosley) that intersect close to the location where the contaminated groundwater was first detected.

The City of Wichita took the lead in assessing and cleaning up the contaminated groundwater, and in the process it created an award-winning groundwater treatment and environmental education center. It thus turned a significant environmental liability into a community asset.

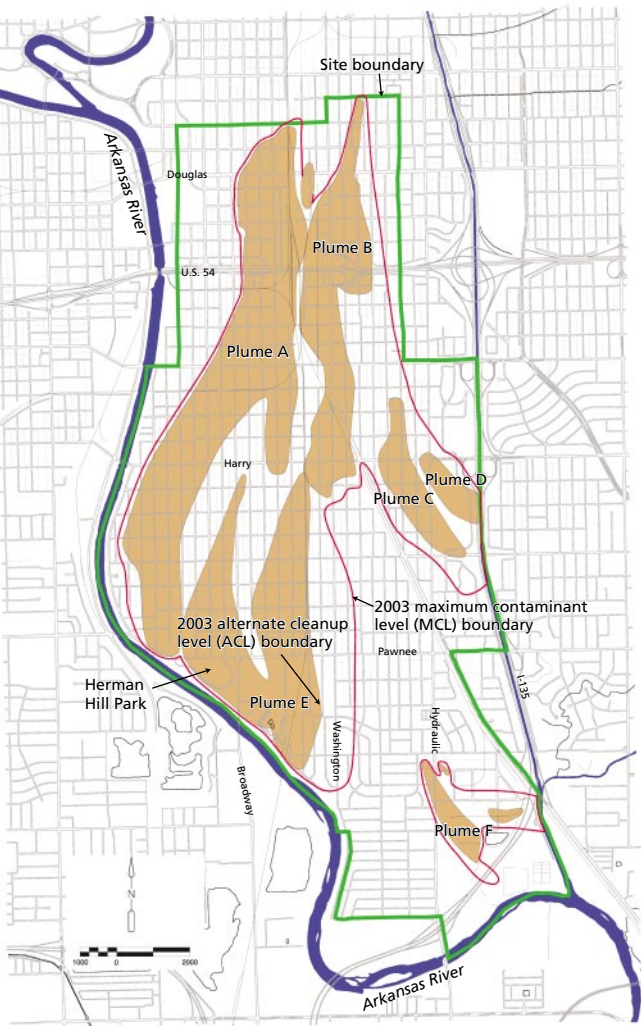
The Gilbert and Mosley Project ultimately included extensive environmental investigations, engineering designs, construction activities, and the operation and maintenance of the groundwater treatment system as the city took the appropriate steps to mitigate the risks posed by the contaminated groundwater. The city hired CDM, headquartered in Cambridge, Massachusetts, for the initial environmental investigations and consulting efforts and later chose it as the designer/builder for the engineering design, construction, and initial operation and maintenance efforts.

Under a cooperative agreement with the U.S. Environmental Protection Agency (EPA), the Kansas DHE conducted a preliminary assessment and site investigation of the Gilbert and Mosley site and documented that the groundwater under

The plaza forming part of the Wichita Area Treatment, Education, and Remediation Center, *opposite*, is a veritable celebration of water. Set in Herman Hill Park, the center, *above*, also has a groundwater treatment building and a building designed to promote environmental education. The water embellishing the new center comes from a system that is remediating contaminated groundwater.



Contaminant Plumes beneath Wichita



downtown Wichita was contaminated with chlorinated hydrocarbons. In 1989 the DHE recommended that an investigation be carried out to obtain the information necessary for placing the site on the EPA’s Superfund National Priorities List.

The contaminated groundwater presented unacceptable risks to the citizens of Wichita, to the environment, and to the local economy. Faced with questions of liability, banks stopped lending to businesses and prospective home buyers. Without action to address the contamination, property values within the area were predicted to plummet by 40 percent. Unless a solution was developed quickly, the federal government was anticipated to invoke the provisions of the Superfund, aggravating what already promised to be a difficult and costly problem.

Although not responsible for the contamination, the city decided to take the initiative for the cleanup and in 1991 signed an agreement with the Kansas DHE to investigate and remediate the site. An investigation to determine the extent of contamination and a feasibility study to evaluate remedial options consistent with federal Superfund laws and guidelines

were completed by CDM for the city and were approved by the DHE in 1994. Later that year, the DHE issued a corrective action decision—equivalent to an EPA record of decision—to establish the regulatory requirements for the cleanup process. Additional sampling and analyses of groundwater and soils were necessary to accomplish the following: comply with that decision, define sources of contamination, conduct pilot bioremediation studies, and document any migration and expansion of the contamination. Based on these additional investigations, an addendum to the remedial investigation and feasibility study was completed in 1999, and the results of the environmental investigations were used extensively in designing the groundwater treatment system.

As part of its remediation plan, the city established a unique partnership between the public and private sectors, one that saw local, state, and federal government bodies working with banks, the real estate community, and the industrial concerns responsible for the contamination. The plan’s fundamental premise would be the city’s acceptance of responsibility for the cleanup of the Gilbert and Mosley site in exchange for funding commitments from public- and private-sector partners. The city government played a leading role in various respects:

- Established an agreement with the Kansas DHE, which was acting on behalf of the EPA;
- Established an agreement with one of the parties responsible for the contamination for payment of that party’s share of the cleanup;
- Issued certificates releasing parties from liability in an effort to revive lending in the area by financial institutions;
- Secured citizen involvement through public meetings and the establishment of an advisory committee;
- Retained a consultant to further investigate the contamination and to design, construct, and initially operate a groundwater treatment system;
- Used the contamination as an opportunity to develop educational resources to help the entire Wichita community better understand the environment.

In assessing the extent of the contamination, more than 5,000 samples of soil, surface water, and groundwater were collected between 1991 and 2001. To reduce costs and increase the number of sampling locations, most of the groundwater samples were collected using direct push (hydraulic) techniques. The groundwater sampling efforts continue today, and the groundwater concentrations at the site are monitored by collecting and analyzing samples from 84 permanent monitoring and extraction wells every three months. Water levels are also measured at more than 240 locations.

Based on the investigations at the Gilbert and Mosley site, six groundwater contaminant plumes (referred to as plumes A through F—see figure above) were defined. The plumes were found to be more than 4 mi (6.4 km) long and 1.5 mi (2.4 km) wide, with approximately 3 billion gal (11.36 million m<sup>3</sup>) of groundwater having chlorinated hydrocarbon concentrations above the maximum contaminant levels (MCLs), which serve as drinking water standards.

Maximum Contaminant Levels and Kansas Department of Health and Environment’s Alternate Cleanup Levels

Contaminant	MCL (µg/L)	10 <sup>-5</sup> risk level (µg/L)	Kansas DHE’s ACL (µg/L)
Tetrachloroethene (PCE)	5	14	14
Trichloroethene (TCE)	5	21	21
cis-1,2-dichloroethene (cis-1,2-DCE)*	70	36.5	70
Vinyl chloride (vc)	2	0.25	2

\*Not a carcinogen. The 10<sup>-5</sup> risk level is based on a hazard index—the sum of hazard quotients for substances that affect the same target organ or organ system—of 1.0.

Throughout most of the plume areas, groundwater concentrations of PCE, TCE, and cis-DCE ranged from 100 to 500 µg/L. Since groundwater flow was causing the contamination to migrate at a rate of 1.2 to 1.7 ft (0.4 to 0.5 m) per day, the extent of the plumes was assessed several times during the investigations and subsequent design work. Even more challenging was determining the sources of the contamination. From initial lists of hundreds of potential sources, more than 20 sources were definitively established with the aid of historical records, interviews, up-gradient/down-gradient groundwater samples, and on-site soil samples. Concentrations of TCE exceeding 17,000 µg/L and of PCE exceeding 19,000 µg/L were found in the groundwater near certain source areas. The sources of the contamination included seven chemical distributors, five dry-cleaning facilities, two manufacturers, two printing establishments, and a recycling firm.

A unique combination of approaches to remediation goals was adopted at the Gilbert and Mosley site. First was the recognition that restoring the aquifer so that it would achieve drinking water standards would not be achievable in a reasonable time frame. An alternative approach—containing the contamination at higher levels and implementing more obtainable remediation goals with frequent evaluation—was seen as being far more cost effective and achievable. To protect public health, care was taken to ensure that the proposed goals fell within the EPA’s range of acceptable risk (10<sup>-4</sup> to 10<sup>-6</sup> additional incidence of cancer for the exposed population). To further reduce any risk to human health, strict institutional controls were put in place and an educational campaign was initiated to prevent future groundwater usage in any area with contaminant concentrations above the MCLs.

After discussions with members of the city staff, the Kansas DHE established alternate cleanup levels (ACLs) for the groundwater remediation, levels that were somewhat higher than the MCLs. The ACLs were set by comparing the federal MCL with the concentration for a particular chemical at a risk of additional cancer incidence no greater than 10<sup>-5</sup> and selecting the higher value. The table above summarizes the MCLs, the con-

centration at a 10<sup>-5</sup> risk level, and the Kansas DHE’s ACLs for the four contaminants of primary concern.

The establishment of the ACLs provided a more realistic goal for the remediation efforts and reduced the total groundwater volume to be treated by 40 percent, thereby also reducing the estimated remediation cost by \$8 million in comparison with the initial projections. The figure on page 52 indicates the overall site boundary (3,850 acres [1,558 ha]) and the locations of the contaminated groundwater plume boundaries based on the MCLs (2,220 acres [898.4 ha]) and on the ACLs (1,350 acres [546.3 ha]).

The six different contaminated groundwater plumes were evaluated, and the city took responsibility for addressing plumes A, B, C, and E. A trust fund set up by the Kansas DHE assumed responsibility for addressing plumes D and F because the contamination in those locations was associated with dry-cleaning operations. The nature and extent of the contamination in plume C are such that so far only groundwater monitoring has been required, whereas for plumes A, B, and E the city has been carrying out active remediation efforts.

Remediation alternatives for plumes A, B, and E were explored using the EPA’s feasibility study approach, a process that involved evaluating remediation technologies on the basis of the characteristics of the sites in question. After the original feasibility study, which evaluated many technologies and process options, additional data were collected and four main alternatives (some with variations) were evaluated in detail:

- Monitored natural attenuation (MNA);
- Pumping and treating at the down-gradient end of the plumes;
- Enhanced pumping and treating;
- Iron walls (the installation of zero-valent iron in trenches to create permeable reactive barriers that would reduce and degrade the chlorinated hydrocarbons by reaction with the iron) and down-gradient pumping and treating;
- Iron walls and monitored natural attenuation;
- In situ bioremediation.



Based on input from a major responsible party, a citizens technical advisory committee, and the Kansas DHE, enhanced pumping and treating was selected based partially on the following considerations:

- MNA was not seen as being effective in meeting the requirements of the Kansas DHE, and it also involved long cleanup times. Although PCE and TCE degrade anaerobically in groundwater, the degradation rates are very slow and the degradation does not proceed beyond *cis*-1,2-DCE.
- Iron walls and in situ bioremediation were new technologies that lacked long-term performance data. The technologies were also the most expensive of those being considered.
- Pumping and treating only at the down-gradient end of the plume would have allowed lateral expansion of the ACL extent and would have taken a long time.
- Enhanced pumping and treating would include additional pumping wells in the plume to shorten cleanup times and minimize lateral expansion of the contamination.

To implement the selected approach, an enhanced groundwater system was constructed to treat plumes A, B, and E. The treatment system consists of 13 extraction wells, 5.3 mi (8.5 km) of influent piping, and a hydraulic venturi air stripper. The system was designed to pump (extraction wells), convey (influent piping), and remove the contaminants (air stripper) at a design flow rate of 860 gpm (3,255 L/min) and a maximum flow rate of 1,095 gpm (4,144 L/min), equivalent to respectively 1.2 mgd (4,542 m<sup>3</sup>/d) and 1.7 mgd (6,435 m<sup>3</sup>/d).

The complexity and scale of the project components created a number of noteworthy design challenges. Extensive groundwater modeling was required to determine the locations of extraction wells and the pumping rates required to provide hydraulic control. The influent piping network design efforts included an extensive evaluation of the piping hydraulics and other considerations associated with the installation and operation of a 5.3 mi (8.5 km) network of pipes with several different segments. Since it was to operate near a residential area and in a public park—the Herman Hill Park—the air stripper treatment system was designed to be as compact and quiet as possible.

The city selected CDM as the designer/builder for the project. The influent piping network was installed by Nowak Construction Company, Inc., of Goddard, Kansas; the extraction wells were constructed by Clarke Well and Equipment, Inc., of Great Bend, Kansas; and the hydraulic venturi air stripper was provided by Hazleton Environmental, Inc., of Hazleton, Pennsylvania. CDM provided the overall construction management and performed some aspects of construction. The design/build approach shortened the construction schedule, facilitated the incorporation of several value engineering improvements, and allowed the project team to efficiently adjust to changes in the scope and design of the project.

The installation of the 5.3 mi (8.5 km) of high-density polyethylene (HDPE) influent piping and the related valves and cleanouts occurred between April and November of 2001. To minimize disruption and property damage during construction, the piping sections were installed through residential and commercial areas and areas of light industry using horizontal directional drilling techniques. Isolation valves (wedge valves with resilient seats) were installed at the pipe junctions to make it possible to isolate piping sections, and cleanout manholes were installed at various locations to provide access for inspection and cleaning efforts. Tracer wires along the entire length of the piping network were installed to aid in future pipe location efforts.

The 13 extraction wells were installed using a reverse-circulation method with potable water as the drilling fluid. Each extraction well consists of a high-efficiency wire-wound stainless steel screen generally installed through the full saturated thickness of the aquifer. The wells are 10 in. (254 mm) in diameter and range in depth from 28 to 38 ft (8.5 to 11.6 m) below the ground surface. A submersible pump (ranging in capacity from 5 to 10 hp [3.7 to 7.5 kW]) is installed in each extraction well, and the pumped groundwater flows through a vertical riser pipe and a pitless adapter section before connecting to the influent piping network. A subsurface valve vault containing a flowmeter, a pressure transducer, a sample port, and a butterfly control valve forms part of each extraction well site, as does a pole- or pedestal-mounted control panel containing a variable-frequency drive, a radio unit, an antenna, and related electrical items.

Operational Summary of Treatment System<sup>a</sup>

Contaminant	NPDES limit (µg/L)	Influent (µg/L)	Effluent (µg/L)
Tetrachloroethene (PCE)	5	58–120	<1–3.5
Trichloroethene (TCE)	5	12–17	<1
<i>cis</i> -1,2-dichloroethene ( <i>cis</i> -1,2-DCE)	70	22–31	1.2–2.8
Vinyl chloride (vc)	2	<1–2.6	<1
Methyl tertiary butyl ether (MTBE)	20 <sup>b</sup>	6.4–21	2.9–9.5

<sup>a</sup>December 2002–March 2004 data.

<sup>b</sup>Non-NPDES goal.



The glass block walls, colorful banners, and unique architectural design of the groundwater treatment building provide an attractive setting for educational tours of the treatment system facilities.

The hydraulic venturi air stripper consists of a subsurface concrete tank and aboveground transfer pumps and hydraulic venturi treatment heads. The concrete tank is subdivided into six modules by a series of baffles and weirs, and each module includes a transfer pump, two treatment heads, a manifold piping section, several hoses, a sample port, and a pressure gauge. Each hydraulic venturi treatment head includes two spray rings through which the groundwater is pumped to create a large amount of surface area in the water flow and to aspirate an air flow through each head. The contaminants volatilize across the surface area, and the water flow is treated by each module in series before entering the final clear-well section. From there the water either drains by gravity to the Arkansas River or is pumped by the clear-well pump to a variety of different water features.

The groundwater treatment system began continuous operation on December 30, 2002, and more than 650 million gal (2.46 million m<sup>3</sup>) of groundwater was pumped and treated during the first year and a half of operation. The extraction well pumping rates were adjusted on the basis of operational data to optimize the aquifer drawdown, and the treatment system handled on average 1.3 mgd (4,921 m<sup>3</sup>/d) during the first year and a half of operation. The primary contaminants and their National Pollutant Discharge Elimination

System (NPDES) limits, influent concentrations, and effluent concentrations are summarized in the table on the previous page.

The Wichita Area Treatment, Education, and Remediation Center, or WATER Center, includes the groundwater treatment building, an environmental education building, and a plaza. The design and construction of the facility unfolded in three phases so that treatment of the contaminated groundwater could, in keeping with the Kansas DHE's regulatory requirements, begin as early as possible. The first phase included the extraction wells, the influent and effluent piping sections, the air stripper, and the groundwater treatment building. The second phase included the environmental education building and the adjoining plaza, and the final phase focused on various embellishments to the surrounding city park.

The WATER Center also was constructed using the design/build approach, and the project team assembled by CDM for design and construction included a large number of firms. In particular, Gossen Livingston Associates, Inc., of Wichita, Kansas, handled the architectural design for the entire project, and Dondlinger & Sons Construction Company, Inc., also of Wichita, served as the building contractor for the groundwater treatment building and the environmental education building.



Enclosing 3,000 sq ft (278.7 m<sup>2</sup>), the circular groundwater treatment building features glass block walls and colored concrete columns and supporting sections. The waffle slab roof was designed using complex computer modeling and detailed hand calculations to precisely predict the anticipated deflections—a critical consideration given the tight deflection limits of the treatment system equipment and the need to avoid transferring any roof loads to the full-height glass block walls. The treatment building contains the groundwater treatment system, a chemical feed system that introduces a sequestering agent, and the conventional mechanical and electrical systems for the building. An aqueduct of colored concrete extending over the treatment building creates a dramatic architectural element.

The environmental education building, which has 6,300 sq ft (585.3 m<sup>2</sup>) of floor space, is on the west side of the WATER Center, across the plaza from the treatment building. It includes a classroom, an exhibit area (with an aquarium and educational exhibits), several offices, public restrooms, and a mechanical area. One of the primary challenges in designing the education building was accommodating the circular geometry of nearly all structural elements and satisfying the desire to locate the building elements on radial grid lines emanating from the middle of the treatment building. Only five straight structural walls are present in the entire education building, and even the roof, constructed using rolled steel I beams and a curved metal deck, follows a curved geometry.

The groundwater treatment building, the environmental education building, and the plaza form the nucleus of the WATER Center. The site improvements implemented in the final phase of the project were designed to enhance Herman Hill Park aesthetically and to provide additional resources for park visitors. A concrete structure with large glass panels uses treated water to provide a cross-sectional view of an aquatic environment. Water from this fish observatory structure overflows to a creek, which was constructed using a liner to minimize water loss in the park's sandy soils. This constructed meandering creek flows for approximately 800 ft (243.8 m) before emptying into the Arkansas River. Signs posted along the creek convey information about the environment to visitors, and new footbridges and sidewalks make the park even more inviting. Additional parking lots and sidewalks were installed as part of the project, and the existing park shelter was rehabilitated and modified to include new plumbing fixtures and other upgrades.

The treated groundwater is used to meet both the aesthetic and the functional needs of the WATER Center. A pumped discharge from the end of the aqueduct structure supplements the numerous fountains in the plaza, and water also cascades down a rippled concrete surface embellished with lines of poetry. The treated water also supplies the aquarium in the education building and the outdoor fish observatory. The treated water is also used to irrigate an extensive section of the park and to supply a station where trucks can obtain water for such nonpotable uses as off-site irrigation, sewer flushing, and dust suppression.

The reuse of the treated water helps to preserve a natural resource and to teach visitors how recycled water can support plant and animal life. Designing the site features that use treated water required innovation, since there are a number of other demands for the water. For example, activating the irrigation system diverts water that normally goes to the fountains. This challenge was overcome through a series of valves, timers, and controls that redirect the water flows as appropriate to satisfy various needs.

In addition to its unique architectural design and the inclusion of aesthetic elements that use water, the WATER Center incorporates lines of poetry that were written expressly for the project. The lines “The life of water never ends” and “The tear and the ocean are sisters” can be read in the cast-in-place concrete parapet wall of the treatment building, and other verses can be found above the glass windows of the fish observatory, above the pool at the lower end of the plaza, and on plaques and pedestals throughout the park. As mentioned previously, lines of poetry adorn the rippled concrete surface that water cascades down. The verses explore and celebrate the life-affirming qualities of water in a manner that is sometimes whimsical and sometimes profound.

From April 2003 through July 2004 the WATER Center hosted a variety of environmental educational endeavors. In addition to 115 on-site programs involving a total of 3,100 participants, 1,200 participants benefited from 49 other programs conducted off-site. More than 970 visitors to the park have toured the WATER Center, and countless other park visitors have enjoyed the creek, the plaza, and the other site features.

A number of school groups and community organizations have benefited from educational programs at the center, and staff members there have conducted interactive educational sessions for visitors of all ages. Numerous species of fish, other aquatic animals, and plants that are native to Kansas are highlighted in the aquarium, the fish observatory, and the creek.

The off-site programs have seen the center's staff visiting schools and community facilities and including educational sessions on the environment in various public events. Indeed, the WATER Center has served as a resource for the entire Wichita community, and its facilities have been used for events ranging from summer programs organized by the park board to private wedding receptions.

The center's resources are anticipated to expand in the future as its hours of operation are increased and staff are added to develop additional educational programs. As the educational resources are supplemented, the city will continue to operate the groundwater treatment system, and various extraction wells will be turned off in the years to come as groundwater monitoring confirms that the remediation in a particular area has been successful.

Earlier this year, the Gilbert and Mosley Project received the Superior Achievement for Excellence in Environmental Engineering Award from the American Academy of Environmental Engineers, a testament to the technical achievements of the project and to the social and economic benefits it has



An aqueduct structure extends over the treatment building and includes a waterfall discharge of the treated water into the plaza pools below. The plaza area also includes extensive landscaping, several fountains, and various architectural features.

conferred. As a result of the city's proactive efforts and leadership, the Gilbert and Mosley Project has successfully achieved its objectives:

- Wichita's citizens have been protected.
- The environment has been protected for future generations.
- A significant educational resource and various community facilities have been created.
- Property values in the area and the city's tax base have been protected.
- Resolution of the environmental liabilities has revitalized commercial development.
- The city has recovered money from responsible parties through arbitration and litigation efforts. The remaining costs are being covered by tax increment financing.

The city has, as it were, turned lemons into lemonade by addressing the contaminated groundwater that posed a threat to human health, the environment, and the local economy. The dramatic architectural elements, water features, and environmental education aspects of the WATER Center combine to make it a landmark facility and a resource that will benefit the entire Wichita community now and in the future. ■

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#### PROJECT CREDITS

Owner: City of Wichita, Kansas

Designer/builder: CDM, Cambridge, Massachusetts

Architect: Gossen Livingston Associates, Inc., Wichita

Building contractor: Dondlinger & Sons Construction Company, Inc., Wichita

Groundwater treatment system vendor: Hazleton Environmental, Inc., Hazleton, Pennsylvania

Influent piping contractor: Nowak Construction, Inc., Goddard, Kansas

Extraction well contractor: Clarke Well and Equipment, Inc., Great Bend, Kansas

Mechanical and electrical engineer (second and third phases): Professional Engineering Consultants, P.A., Wichita

Mechanical contractor: Professional Mechanical Contractors, Inc., Wichita

Electrical contractor (first phase): Total Electric, Inc., Wichita

Electrical contractor (second and third phases): Shelley Electric, Inc., Wichita